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Renewable energy activities in Senegal: a review

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Abstract

Like many countries in Africa, Senegal is facing economical decline, energy crisis and serious desertification problem in rural areas. These issues could be removed if renewable energy is used as a primary source of energy in rural areas. What is required is a strategy to implement renewable energy technologies at large scale. The government and many non-governmental organisations (NGOs) have tried to comprehend and have strived to address the problem of energy. This paper presents a review of activities in the field of renewable energy applications in Senegal, which goes back to the mid 1970s and will discuss the socio-economic benefits that the country has derived from these environmentally sound and appropriate sources of energy. The development and trial of systems were mostly funded so far by donor agencies in collaboration with government and NGOs. Among the applications being supported are solar lighting, water pumping and small power plants. Recent efforts have been aimed at restructuring the programmes and giving them a market orientation. Future trends, some suggestions and recommendations for successful dissemination of renewable energy sources are also drawn. The present situation is seen to be much more promising and favourable for renewable energy.

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1. Introduction

1.1. Geography and economy background

Senegal, the most westerly country of Africa, lies between 12 and 17°N with a total area of about 196,700 km^2, and a population of over 9 million people (according to the last census of May 1988, the total population was 6,896,800 inhabitants). The population growth rate is around 3%. More than 30% of the country's population is urban, of whom about 50% live in the overcrowded Dakar region. Most of the country is flat, but there are some low hills up to 500 m high toward the Southeast. The soil is dry and sandy. The savannah with brushwood and baobab runs from the North to the tropical forests in the South. There are four rivers: the Senegal (1700 km), the Gambia which is Senegalese over only 300 km, the Casamance (300 km) and the Saloum. The rainy season is short, little more than 3 months, the annual average of rainfall ranges from 300 mm in the North to 1600 mm in the South. Due to its buffer situation between the Atlantic Ocean and the large warm and dry Sahelian region, the climate is very particular. The average ambient temperature fluctuates between 18 and 31°C, with a humidity generally around 80%.

Senegal's economy remains essentially agricultural. However, the agricultural basis of the economy has been affected by several years of drought and gradual desertification of large tracts of land, following as a result hardship to rural population and a substantial migration to Dakar and other big cities. The principal food crops are millet, sorghum, rice, maize, cassava and sweet potatoes. Groundnuts are the leading cash crop, but the area under cultivation has declined in recent years. There are few banana and mango plantations. The government has attempted to reduce the dependence on groundnuts by diversifying cash and food crops, in particular by expanding cotton, rice, sugar cane, 'niébé' a variety of bean and market garden produce. The livestock was hit by the lack of rainfall and the national herd of cattle is still well below the 1970 figure. Fishing, phosphate mining and sightseeing have outstripped groundnuts as the principal sources of foreign currency. Senegal's mineral resources are relatively poor. Mining has so far limited to calcium phosphates (aluminium phosphates are also present) and phosphate fertilizers are produced. The development of a valuable gold reserves located at Sabadola (in the Southeast) started two years ago. Considerable quantity of high grade iron ore has been located at Falémé, in the Southeast. Commercial viable titanium deposits were discovered in 1991. Reserves of natural gas are exploited in the Diam Nadio area (30 km from Dakar), and deposits of petroleum have been located in the Dôme Flore field, off the Casamance coast, but these reserves are not currently economically feasible. Peat deposits were also discovered in the Niayes area and its development is being examined with external financial support. Although these reserves have proved smaller than expected, it was hopped that they would provide fuel for electricity generator and also substitute for firewood as domestic fuel.

1.2. Energy status

Senegal has poor indigenous energy sources and depend heavily on imported energy. Since Senegal has not lifted its oil reserves yet, all petroleum products are imported (28% of total imports) and are largely consumed by the transport sector. Electricity power is supplied from six thermal stations with a total capacity of 287 MW. Gas deposit discovered at Diam Niadio was put to fire the Cap des Biches power station, while the five remaining are oil fired stations. Energy generated is mainly used in urban areas by factories and household (lighting and electrical appliances). The existing capacity cannot meet the increasing annual demand of energy, resulting in load shedding and serious power fluctuations. To supply the energy requirements in the future the installed power stations will be renewed and new stations will be built. It has been estimated that the present energy shortfall results in an annual loss of production of about 2%, despite large resources poured into the power sector. In light of the increasing deficit in the balance of payments, further government spending is difficult. Restoration of the financial health of the state-owned utility (SENELEC) and improvement of their operational performance are the most critical issue in the energy sector. In 1997, the government of Senegal embarked on a power sector reform program with the assistance of the World Bank with emphasis on privatisation of the company through the sale of SENELEC shares to a strategic investor and public sale in order to widen its ownership, private sector participation in power generation and distribution. The reliance on oil imports results in greater trade imbalance, larger national debts, a weaker and less stable economy, further compounded by the sudden devaluation of the CFA franc by 50% in January 1994. To address energy shortage, the government expected a lot on work to begin in 1982 on the Manantali hydroelectric plant, on the Senegal river, in a joint scheme with Mauritania and Mali. It was scheduled to produce 800 GWh per year of which 280 GWh per year will be absorbed by Senegal. The development of iron deposits would require new sources of electricity and only the Manantali dam could provide such a source. However, the plant's full generating power scheduled for 1999 will not be available for some time.

Traditional fuels still account for 58% of the country's energy consumption. The bulk of the population in rural areas uses firewood or charcoal for cooking. In 1992, Senegalese households had consumed roughly equivalent to 1,500,000 tonnes oil of fuelwood, while the amount of commercial energy was 660,000 tonnes oil equivalent. Liquid petroleum gas (LPG) for domestic use represented about 6% of the total commercial energy. Direct burning of the basic form of biomass (firewood, charcoal and crop residues) represents 93% of rural energy consumption. Fuelwood is the only energy that has no impact on the trade balance. In addition, production of charcoal generates employment and provides opportunity for rural household to earn cash. However, deforestation and soil erosion resulting from unsustainable wood gathering and burning is a serious environmental issue in Senegal. It has been estimated that forests diminish at a rate around 25%. According to high figure of fuelwood reliance, one can see that

rural electrification is poor, and with the reforms currently undertaken in the power sector, the electricity grid will remain a distant dream for most of the rural population.

After the oil crisis in the 1970s, there was a significant and growing interest in Senegal to develop alternative renewable energy and efficient use of energy. In the mid 1980s, the government launched the Energy Redeployment in Senegal (RENES) aimed to promote energy-efficient use, renewable energy technologies and afforestation.

2. Renewable energy development

Senegal is a sunny country with about 3000 sunny h per year and an average of solar energy received is estimated around 2000 kWh/m^2/year. The daily average solar radiation for the year on a horizontal surface and the average sunshine duration recorded at four typical regions of Senegal are shown on Table 1. One can see that solar radiation in Senegal is particularly good and the radiation intensity and sunny h in a day are remarkably different in the North and the South. Days with low solar radiation occur rarely in the North, while in the South a larger variability of daily global radiation is observed. Information on the availability and seasonal variability of global solar radiation for most regions of the country is sufficient for successful operation of solar powered devices that do not require focusing by concentrator.

2.1. Biomass

The common methods available for converting the basic biomass to thermal energy have efficiencies of 20% at best. In order to reduce the growth in fuelwood consumption, research and demonstration have been carried out to develop improved cookstoves. Improving wood and charcoal burning is also a healthy necessity; traditional woodfires are known to cause respiratory diseases. In 1980, the Renewable Energy Research Centre (CERER) started a cookstoves research and applications programme with funding from international agencies. The main

Table 1
Monthly mean of daily solar radiation and sunshine duration averaged over the year for some typical stations

City	Global solar radiation (kW/m^2/day)			Duration of radiation (h/day)		
	Average	Maximum	Minimum	Average	Maximun	Minimum
Dakar	5.8	6.9 (April)	4.7 (December)	8.6	9.9 (April)	7.5 (August)
Louga	5.6	6.6 (May)	4.4 (December)	8.3	9.5 (May)	7.1 (December)
Tambacounda	5.3	6.3 (April)	4.3 (December)	8.7	10.2 (March)	7.2 (August)
Ziguinchor	4.3	5.2 (April)	3.5 (January)	8.0	9.5 (May)	5.4 (August)

objective of that programme was to satisfy the average family's cooking requirements which will save fuelwood, as well as will reduce health effects from smoke inhalation.

For rural area the 'Ban ak Suf' (sand and mood) woodstove was supposed to provide a transition from a traditional three-stone open fire to an enclosed fire. Even though a fuel saving of 40% was claimed [1], successful integration of these stoves into daily cooking activities and their acceptance by the community was not achieved because technical advice and assistance were not sufficiently relayed in the community based organizations. Most of the women in the areas where it has been on trial did not find the product user friendly, in addition, open fires have other functions such as lighting, space heating and insect repellent qualities not found in the woodstove [2]. On the contrary, the charcoal stoves 'Sakanal' improved metallic stove and 'Jambar' with a ceramic insulating linear reducing charcoal input by 40–60% were well received in urban area. Charcoal is mainly an urban commodity, and the poorest urban family spend a significant fraction of their income to purchase charcoal. They are also more sensible to the sharp increase of oil prices. The quite successful dissemination of improved cookstoves was attributed to their affordability, acceptability and availability. In fact cookstoves training were offered to local artisans. So cheap and fuel efficient cookstoves are now mass-produced. At the same time, the government has also initiated an accompanying policy of planting trees and subsidising LPG. A national plan against deforestation and fuelwood shortage was brought out through campaign via mass-media and provision of free seedlings for planting around home, at school, along roads, etc.

There are tonnes of leaves, sawdust, crop straw and husks, but current disposal methods of these biomass residues included burning and dumping on surrounding sites. These residues have no economic value other than energy generation. But only two agro-industrial companies, the National Company of Oleaginous (SONACOS) and the Sugar Cane Company (CSS), generate electricity from biomass residues. However, recently a small enterprise (Delta 2000) has been attempting to valorise the lignocellulosic biomass with a prototype unit for briquetting crop residues, namely rice stubble and groundnuts husks. Delta in collaboration with CERER (for technical advice and support) is conducting on-going surveys for improving methods of production and market analysis. A new factory (Charbonage du Sénégal-CDS) has been built by private investors at Dakar for carbonisation of agricultural residues. The product is now available with a good commercial network in Dakar area.

Another attempt to address fuelwood problems and deforestation is through biogas production. At the end of 1994, ten biodigesters were in operation for lighting, cooking, pumping, refrigeration and grain milling. The viability of small-scale family type biodigesters designed for cooking and lighting purposes has been demonstrated by ENDA Tiers-Monde, a NGO working on environmental issues and sustainable development. The National Agronomy Research Centre (CNRA) has developed a biogasification/diesel dual engine saving 75% of fuel to supply electricity for water pumping. Biomethanisation that employs anaerobic digestion

of biomass has not been disseminated satisfactorily, despite efforts to transfer biogasifier technology to local users. Major factors behind the development and diffusion of biogas technology are: low degree of operability, lack of feedstock and high initial investment costs. In fact, to introduce biogas technology, emphasis was put on the use of animal manure as the sole feedstock, while little attention was given to other potentials for biodigester feedstock. These include municipal solid wastes and wastewater and agro-industrial residues. On the basis of their organic matter content, these materials have an enormous potential for conversion into biogas and peasantry usually vulnerable to price and supply fluctuations could benefit from biogas production for household cooking and lighting. However, acceptance of biogas technology by the community will depend on including community representatives and decision makers in all stages of development and dissemination.

2.2. Wind energy

In Senegal, wind energy offers poor potential because of very low wind speed and abrupt variations in peak wind speed condition. The annual wind velocities over a major part of the country are 2–3 m/s. Only a narrow coastal strip of 50 km width, between Dakar and St-Louis, has wind velocities which could just meet the minimum desired limit of 5 m/s. The extractable energy in this area is estimated at 1.5 kWh/m^2 daily. Wind energy is well suited for underground water that are shallow enough to be lifted at an affordable cost and intermittent power requirements. Experiences in wind energy was developed by CERER and the Polytechnic College. Over 400 windmills for water pumping were installed in the mid 1980s, half of them were provided by the Argentinian government. Many different types and sizes system units were also tested for small-scale applications (less than 10 kW). Due to the difficulties of obtaining spare parts 70% of these machines are not working now. A programme of rehabilitation is currently underway.

2.3. Solar energy

The government of Senegal recognized the potential of the solar energy as far back as when the country gained independence in 1960. The first institute devoted to solar energy research was established at the University of Dakar in 1962 — Institute of Meteorological Physics (IPM). Solar radiation measurements were the first activities undertaken by researchers of the institute. These are necessary to construct any solar system at any location. Masson and Girardier [3] and Girardier and Alexandroff [4] set up a pumping system powered by solar energy. To extend the experience gained in thermal utilisation of solar energy and to embark new areas of research in solar energy, this institute was renamed CERER in 1975. It was just after a drastic drought which hit Senegal along with others Sahelian countries and the first oil crisis.

2.3.1. Solar thermal energy

Research, development and application of solar thermal energy technologies have been underway, focusing in the earliest period in solar pumping and solar power technology. In the late 1970s, six pumping systems of 1–30 kW were installed and tested and a solar power plant of 25 kW was built [5]. Unfortunately, information revealed that these systems were not working efficiently compared to diesel systems. Lack of awareness, difficulties of maintenance and repair, as well as high costs involved were the main reason for dropping this field of activity. Solar water heating, solar drying, solar cooking are some of the preferred areas of research in solar thermal applications.

Solar heating is the most attractive way of solar energy application, due to its simplicity to construct and negligible maintenance and running cost. Senegal is characterised by a widely varied climate and the coast is remarkably cool. Production of hot water for domestic applications using solar heating system will conserve electrical energy that Senegal needs for its development. Several research works from CERER have been done. The performance characteristic of the system was experimentally determined and acceptable efficiency was obtained. A factory, SINAES, manufacturing solar water heaters, was established. Products have been installed in many private dwellings, hospitals, school and hotels. The narrow market and negligible revenue streams have brought the company to the brink of bankruptcy.

Drying in rural areas is largely accomplished by direct exposure of products to sunlight. In the mid 1980s, experimental units for solar drying were installed at CERER and studies conducted in collaboration with the Food Technology Institute (ITA). More than 150 solar dryers with natural and forced convection have been designed and fabricated, with local artisans participation, for village use in a small scale operation. Most of them worked on average for six months due to the life time of the plastic sheet. Solar dryers involve mainly wild grown medicinal plants, fruits, vegetables and fish. The dried produce were more hygienic but with higher selling price. The project was not continued due to the lack of funds and follow-up objectives and little awareness has been created among the population of the use of solar drying in the agricultural sector. A multi-shelf forced convection solar dryers with a solar air type collector used on a semi-industrial scale was tried in the fishing area of St-Louis with, a daily holding capacity of 375 kg of fish. Many possibilities still remain for technical improvement which will help to improve efficiency and lower the cost [6]. Solar dryers are not commercially available in Senegal and no identifiable dealer exists yet.

In the arid interior, fresh surface water is quite inexistant and groundwater is often brackish or contains high levels of nitrates and fluorides. The use of solar stills is a realistic option to secure water for drinking and other livelihood activities. The CERER was solicited by some rural communities and NGOs to assist them in addressing a specific need. Several units of solar still were fabricated, local artisans were also trained. The CNRA has installed 50 m^2 of solar still to meet distilled water needs for research purpose. Solar stills are not

commercially available and interested users would have to contact the research institution.

Solar cooking has not achieved great popularity and widespread dissemination. In the earliest 1980s, paraboloid concentrator solar cookers were introduced. After sporadic demonstrations, cookers were abandoned in the back yards. The reasons behind these drawbacks are linked to immature design and technical constraints such as reflectors to adjust often and temperature decrease when clouds appear. Furthermore the cooker was unsuited to most local dishes. At present, demonstration and test of solar box cookers are being carried out by NGOs. These cookers seem more easy to use and may allow slow cooking of rice.

2.3.2. Solar PV system

The applications of photovoltaic energy have gained popularity in Senegal over many years. The first PV pumping system was installed and tested at the Faculty of Science in 1976 [7,8]. Realizing the reliability and low maintenance of PV systems, the government and international aid institutions established a broad-based co-operative strategy for dissemination of PV systems. Solar PV is one of the key projects underway, particularly for decentralized applications in rural areas. Indoor lighting and PV water pumping provide the most basic services in Senegal. Over 2100 solar PV systems aggregating 800 kWp have been installed. The distribution (%) of solar PV systems installed is shown in Fig. 1.

The most important and successful project was the Senegalese–German programme, namely GTZ project. From 1989 to 1994, the total wattage installed by the project was 154.9 kWp. This project was aimed to undertake several tasks for the implementation of PV technology for rural electrification. These tasks are to handle system components and specifying area of testing, selection of private sector companies to develop business, monitoring and establishing of developing and marketing plan.

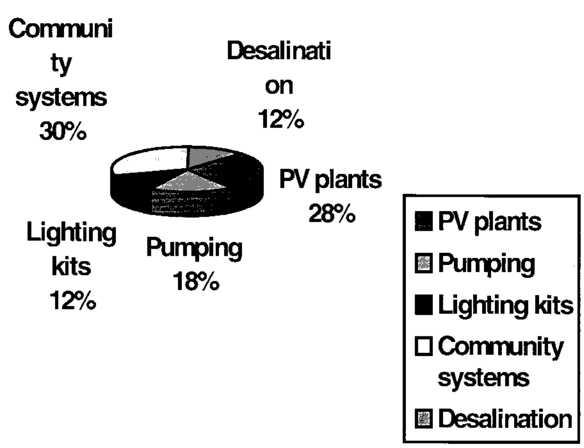

Fig. 1. Solar PV systems installed in Senegal [9].

Several kW of PV power have been installed through the country to provide electricity for houses and community buildings. Individual PV lighting kits have been adopted for domestic usage. Each includes a 50 Wp module, 4 lamps of 10 W, a 50 Ah storage battery and a regulator. A TV set or a radio can also be incorporated in the application. Solar portable lanterns have become also very popular for providing light. A typical lantern uses a 5–8 Wp module and a fluorescent bulb. The battery incorporated is charged during the day and can provide power to the lamp for about 5 h at night. By the end of 1994, 1600 stand-alone family kits and 500 solar lanterns were in use in various regions corresponding to a total wattage of 87.6 kWp. In the programme of solar lanterns, selected village youth have been given the solar lanterns and provided training for their maintenance. These youth in turn rent the lantern on a daily basis. A survey [6] indicated that all users were satisfied with lanterns, and 51% would like to acquire their own instead of renting. Countless numbers of such lanterns were introduced by nationals living abroad.

Community systems for rural health centres and adult education centres are generally in the range of 100 Wp–1 kWp and may provide 2.5 kWh/day. Up to lighting, the systems power TV sets, refrigerators, fans and other electronic devices. There are over 80 community systems in operation across the country, with a cumulative wattage of 37 kWp. About 43% of these systems provide electricity for rural health centres. Efforts are being made by some international aids (La Fondation Energies pour le Monde and WHO) to introduce 40 more rural health centres planned totally to operate by PV solar system. Small-power plants in the range 2–100 kWp have been installed in about 10 villages. These systems provide power for street lights, domestic lights and community utilities (TV, radio, refrigerator, solar water desalination, millet mill, etc.). Tables 2 and 3 illustrate the above points and provide a breakdown on solar PV applications in various regions of Senegal.

Water pumping has traditionally been one of the most important application for PV. The supply of drinking water is of vital importance for rural population.

Table 2
Community systems projects carried out

Region	Period	Number of systems	Installed power (kWp)	Capacity (kWp/year)
Dakar	1991–1993	4	0.55	600
Diourbel	1991	1	0.11	150
Fatick	1989–1992	9	4.42	5390
Kaolack	1990	6	0.66	830
Kolda	1992	9	1.1	1850
Louga	1991–1993	3	0.70	950
St-Louis	1988–1993	14	3.20	3600
Tambacounda	1992–1993	11	2.40	2850
Thiès	1988–1993	15	21.30	26,470
Ziguinchor	1990–1994	12	2.45	2975

Table 3
Centralized PV power plants applications

Site (region)	Starting date	Number of households	Power (kWp)	Capacity (kWh/yr)
Niaga (Dakar)	1982	–	5.3	6000
Diaoulé (Fatick)	1989	217	21.5	25,000
Ndiébel (Kaolack)	1990	221	19.8	23,000
Touba Ndiaye (Louga)	1987	200	1.0	1250
Mbakhana (St-Louis)	1989	Health centre and irrigation	25	30,000
Notto (Thiès)	1992	300	10	12,000
Tandième	1996	100	5.0	6000
Bassar[a]	1996	Lighting (home and street) and desalination	80.0	–
Bassoul[a]	1996	Lighting (home and street) and desalination	80.0	–
Dionewar[a] (Fatick)	1996	Lighting (home and street) and desalination	100.0	–
Niodior[a] (Fatick)	1996	Lighting (home and street) and desalination	100.0	–
Djirna[a]	1996	–	10.0	–

[a] PV diesel generator hybrid system.

In most areas, groundwater is the main or the only source of water for rural dwellers. Table 4 shows details of PV water pumping using 0.1–5 kWp. About one-third of the systems are used for irrigation. It has been so far found that more than 75% of systems are functioning. Almost all the malfunctioning systems are related to motors and pumps. The rate of installation increases every year. Out of the programme, we do not know the number of pump systems installed by individual purchasers.

Other applications in solar PV are powering remote relay stations and centralized battery charging for rural villages. The National Company of Telecommunication (SONATEL) has already installed over 50 signal repeating stations supplied by PV panels in the range of 40 Wp–5 kWp. A major expansion of the telecommunication network as targeted by the privatization of the

Table 4
PV water pumping systems installed in various regions

Region	Period	Number of pumps	Installed power (kWp)	Remarks
Diourbel	1978	1	0.9	Out of order
Fatick	1988–1990	5	11.1	Drinking water
Kaolack	1990	2	9.5	Drinking water
Kolda	1994	3	13.3	Drinking water
Louga	1994	1	3.1	Drinking water
St-Louis	1989–1993	36	84.0	6 out of order, 17 for irrigation
Tambacounda	1994	4	16.4	Drinking water
Thiès	1980–1989	14	33.2	7 out of order, 2 for irrigation
Ziguinchor	1987–1994	8	4.7	1 For irrigation

SONATEL and the liberalization of the market for value-added and other services such as cellular phone systems (GMS phones are now provided by SONATEL and soon by private sector) will create a need for rural radio-telephone and establish a major market for PV system. The CERER, with financial support of the French Environment and Energy Control Agency (ADEME), installed three pilot solar PV powered battery stations in order to meet battery charging needs of three rural villages. Inhabitants who own radio-cassettes or lanterns bring their batteries to the station for recharging.

3. Discussion

Fuelwood and kerosene are the major sources of energy in rural areas. Promoting renewable energy sources for rural energy requirements in conjunction with alleviation of rural poverty, diversification of energy resources and reduction of oil imports are needed to shift the economical growth towards greater sustainability, as well as environmental and social stability. Information on the socio-economic and environmental aspects are limited. The available data are scattered and least quantified. So, it is difficult to assess full impact of renewable energy in the country both socio-economically and environmentally.

There are more than 13,000 villages in Senegal, and most of them are unconnected to the national grid. It is estimated that only 5% of rural households are hooked on the grid. The electrification by grid extension or secondary power station can only reach a small minority of the population in rural areas. In view of the dispersion of localities and the low demand, the cost of production, transmission and especially distribution of electricity would be prohibitively expensive. Bureaucratic and political interference are also limiting factors. Decentralised PV systems like stand-alone family lighting kit could effectively become a viable option in these areas. One of the essential features of the family lighting kit is its modularity, it can be tailored to the real needs of each consumer. Other advantages are:

- They do not require any grid lines to take the power to each house
- With no distribution and transmission lines losses are eliminated and theft of electricity is avoided.

The installation of solar PV technology in some rural localities of Senegal has brought significant changes in the awareness of people and also improved their quality of life. The initial reaction of the villagers was one of apathy and disinterest. However, when the community system became functional, the situation changed radically, people came in groups to watch TV. A large number of people from the neighbouring villages were also attracted. The initial apathy first gave rise to curiosity and then to total acceptance and a feeling of pride. With lighting available, living habits improve. Leisure and entertainment from TV programmes which were a short time ago a privilege of urban life could be routinely viewed by rural families. Public life was almost inexistant before street lights were

operational. Villages were seen teeming with life after darkness till late hours under the solar light. In the community centres, adult education programmes, meeting of villagers and social gatherings were regular features.

Kerosene lanterns and candles provide inadequate lighting, cause pollution and entail fire hazard. PV lighting is more stable and more bright. With this good quality light, school children get better vision for their homework, with less or no strain, productive activities can also be carried out during the evening hours by housewives. PV systems provide also better lighting and at lower cost than dry-cell batteries [6]. The dry-cell batteries not only are often of poor quality, but they can take a significant fraction of the low income of a poor family. They have a short lifetime and there is no proper disposal.

After the installation of PV water pumping systems, water requirements for gardens, vegetables, cattle breeding and cash crops had yielded substantial gains to peasantry and had increased their income. Drinking water was also secured on long term basis. This is a major social benefit, as impure drinking water is responsible for a large fraction of infant mortality. The fact that a storage tank is included in the solar water pumping system means reducing the drudgery of fetching water for women. Beside the coastal area, there are several islands lacking in potable water for drinking. Using solar water desalination technology to tackle the water shortage problem has had a real impact on the standard of living within these islands.

Provision of health care in rural areas is a major concern, therefore rural health centres are integral parts of the primary health care systems in Senegal. However, their ability to deliver basic health services depends on the availability of electrical energy, particularly for vaccine storage, lighting and safe water. Family health, especially maternal and infant welfare, has been improved when health centres in rural areas were upgraded by providing them with solar PV energy. This has ensured, to some extent, the success of the immunization programme.

The overall effect of community facilities such as school, health centres or water pumping can contribute significantly to welfare and rural development [10]. And the tendency to emigrate from rural areas to urban cities has been stemmed, even a quantum leap in the quality of life has been raised. Above all, rural electrification is viewed as a mean of narrowing the gap between the life style in urban and rural areas. It can also be regarded as an extension of benefits deriving from national overall economic development to the rural folk. Lack of electricity will deprive entire populations of rural areas access to better living standards and will lead to social tensions and political instability.

Satisfactory performance of PV has helped in the introduction of many more similar installation in the country. Since the market has been shifted from publicly funded applications to a private/consumer market, to promote solar technologies and to create an environment conducive for their commercialization, the government regulated that no import custom duty and sales tax (VAT) should be levied on solar PV components and solar heaters entering in the country. About 12 small enterprises selling PV systems have been identified. All PV dealers offer after sales services and annual maintenance contracts. The approximate cost of a

PV family lighting kit ranges between 270,000 and 625,000 FCFA (600 FCFA = 1 $US) which seems to be high for rural areas. Over 50% of the rural households have an annual income of less than 250,000 FCFA, which is defined as the poverty line. Another 30% have incomes between 250,000 and 500,000 FCFA. At present, the low demand (10–15% rural households), the low income of rural populations, high cost of PV systems, little access to commercial bank loans are the main hindrances against the implementation and the market expansion of PV systems. The fact that PV panels and accessories are free of duty makes them cheaper than would otherwise have been the case. However, it is insufficient as the sole measure to boost the solar PV market. In addition, government and financial organization should provide long-term and low-interest loans to make individual household PV systems more affordable to the rural population. Besides the incentives mentioned above, direct government subsidies are highly desirable, similar to what it has been done for electricity and LPG. A new finance scheme has been formulated to provide lighting systems in villages, involving community groups and decentralized rural credit societies. At present, there are 10 rural associations or NGOs specializing in renewable energy and rural development. Some of them operate as a micro-enterprise, with other activities such as poultry and cattle breeding, sale of cattle fattening products, etc. These associations are linked by a federation and provide credit to buyers of solar systems. Each group selects clients and monitors their repayments. The credit scheme has enabled 1705 solar systems more to be installed to households. Women are very actively investing in these associations. About 60% of the membership are women. There are at least two technicians in each group for maintenance.

Provision of electricity has many effects which can benefit women. However, PV does not solve the urgent need of a satisfying energy source for cooking. Domestic cooking is a major consumer of lignocellulosic biomass. Women are solely involved in this activity. To collect tree biomass, women, sometimes assisted by children, spend several hours a day. Though, it is done free, releasing women from doing mundane work will empower them. Indeed, women will get more time for self-advancement: adult literacy, actualisation about nutrition, family planning, skills training such as sewing, etc. thus better child care, gardening and hence increased revenue. This affects the nutrition and the health of the entire family.

Ecological and environmental impacts may be raised for the use of lignocellulosic biomass. The destruction of fragile forest resources has led to desertification and reduced agricultural productivity as a result of declining soil fertility, decreased groundwater recharge, loss of biodiversity and other micro-climate effects. Deforestation has a negative effect on both the environment and women's health, bringing in less income, necessitating more work and increasing the downward spiral of poverty. Education, especially of girls, suffers when fuelwood and water resources are scarce.

Incomplete combustion of fuelwood from traditional stoves generates harmful air pollutants such as carbon monoxide, suspended particulates, sulphur oxides, nitrogen oxides and hydrocarbons which have been linked to eyes and respiratory diseases [11,12]. Environmental degradation thus affects not only their ability to

look after their family's nutrition and health, but also their own health, well-being and income generating activities. Introduction of renewable energy is the quickest way to initiate a programme of social upliftment for the majority of people in rural areas. With the use of improved wood stoves, biogas or solar cooker women find a great relief at home as pollution is minimized. On a global level, burning wood releases carbon dioxide and other greenhouse gases which threaten a global warming. Thus the fact that forests are harvested at a very rapid rate combined with increased fossil fuel consumption as a result of population growth and economic development is contributing to localized and global environmental degradation. A more aggressive policy for intensifying the energy tree plantation will be one of the options for supplying renewable energy to rural dwellers and provide an opportunity to balance carbon dioxide and other greenhouse gas emissions, as wood is a natural greenhouse fuel [13].

4. Conclusion

In the last two decades, a lot of activities in the field of renewable energy have been done and needed to be encouraged and continued. Although renewable energy applications, not including biomass, only provided in 1994 1% of the total energy consumption in rural areas. These applications have played an important role in social and economic development. Renewable energy has great potential for further development in rural areas. There are many renewable energy technologies which can be utilised in Senegal, solar energy harnessed by PV technology for lighting and pumping water, biogas, improved cookstove and solar box cooker for cooking requirements. However appropriate financing of this purchase is one of the key impediments to accelerate dissemination of renewable energy. In addition, careful attention should be paid to local customs, social hierarchy and including women in consultation, discussion and technology training. A gradual change from conventional energy to renewable energy would benefit both the economy and the nation as a whole. There is need to create a government agency dedicated to renewable energy promotion, by supporting comprehensive economic energy analyses, encouraging household sector to use renewable energy instead of conventional energy, managing and administering credit funds and subsidies. In other words, the overall objective of the agency is to implement a national policy that will encompass the supply of adequate, reliable, sustainable and safe energy to all sectors of the national economy, by reducing our dependence on oil importation and consequently trade imbalance.

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